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CLASSIFICATION

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## CANADIAN PATENT

LINER EXPANDER

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Granted to Pan American Petroleum Corporation, Tulsa, Oklahoma, U.S.A.

APPLICATION No. 897, 460

FILED

PRIORITY DATE

No. OF CLAIMS

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#### LINER EXPANDER

This invention relates to a constant force spring device, and more particularly, to a device for expanding a metallic liner wherein an expanding die is urged against the liner by a constant force spring device.

Heretofore, a method and apparatus have been developed for installing an expanded metallic liner in an oil well or other conduit. Typically, a corrugated steel liner is inserted in a conduit which is to be lined, the greatest peripheral dimension of the liner being slightly less than the inside diameter of the conduit. An expanding tool is passed through the liner placed in the conduit, and a first-stage expanding die causes a gross plastic deformation of the liner, which is expanded outwardly against the inside of the conduit. A second-stage die on the tool then provides an additional finer deformation of the liner to provide a smoother, more finished surface on the inside of the liner and to assure more complete contact between the conduit and the liner. In a typical design of this type expanding tool, the frictional drag of the first-stage die supplies the expanding force for the second-stage die, which expanding force is a direct function of the strength, or wall thickness, of the conduit in which the liner is being installed. For example, in lining oil well casing, heavy wall casing may cause a very high frictional force which results in excessive pressure being required to push the expander through the liner. The application of the great forces required may result in rupture of the casing or in breaking the installing tool. In instances where the internal diameter of the conduit is somewhat less than that anticipated, the resulting forces can cause the tool to become stuck in the casing, or otherwise cause damage to the casing and the tool. In other designs, such as where a cantilever spring arrangement is employed in connection with the secondstage die, various difficulties are encountered in obtaining a spring mechanism having the desired strength in combination with the other spring characteristics, and with the tool dragging against the inside wall of the conduit after being passed through the liner.

Since tools of the type mentioned above often are employed in wells deep in the ground, it is highly preferable that a tool be used which under no circumstances will become stuck in the well or cause damage to the well. Any such trouble occurring in a well can result in considerable loss in time and great expense in making repairs.

An object of the present invention is a device for applying a constant force to an expanding die or other similar apparatus so that a preselected maximum force is exerted against a work piece. Another object is an improved expanding tool for installing metallic liners in a conduit, which expanding tool can apply no greater than a predetermined force to the liner being installed in the conduit. Still another object of the invention is an economical and easily fabricated constant force spring device. A further object is a rugged, easy-to-operate expanding tool employing such a spring device. These and other objects of the invention will become apparent by reference to the following description of the invention.

In accordance with the present invention there is provided a constant force spring device which comprises a body member, an elongated column element adjacent said body member, bearing plate members contacting the two ends of said column at least one of said bearing plate members being longitudinally movable in respect of the other and stop means on said body member to limit the deflection of said column element to prevent permanent deformation of said column element upon the application of a compressive load thereto. In one embodiment of the invention, the foregoing constant force spring device is employed in a tool for expanding a metallic liner inside a conduit, said constant force spring device being positioned on said tool to urge an expanding die member against the liner being installed in the conduit by a substantially constant force.

My invention will be better understood by reference to the following description and the accompanying drawings wherein:

Figures 1A, 1B and 1C, taken together, constitute a partial sectional view of a preferred embodiment of a liner expanding tool according to the present invention; and

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Figure 2 is a sectional view of the apparatus of Figure 1A taken at line 2-2; and

Figure 3 is a typical plot of applied Load versus Deflection for the constant force spring device of the invention.

Referring to the drawings, Figure 1A is the bottom portion of a liner expanding tool for use in installing a metallic liner in a well, while Figure 1B illustrates the middle section of such a tool and Figure 1C represents the upper section of the tool. The expanding tool 11 is attached to standard well tubing 12 by coupling 13 and, typically, may be lowered from the surface through a well casing (not shown) to a point in the casing at which it is desired to install a metallic liner. Before inserting the tool into the well, an elongated vertically corrugated liner 14 fabricated from mild steel, or other suitable malleable material, is placed on the tool. The corrugated liner is secured in position by contact at its upper end with a cylindrical shoulder member 16 and, at its lower end by contact with a first-stage expanding die 17 in the form of a truncated circular cone which serves as a firststage expanding die in the manner hereinafter described. The expanding die is fixedly attached to a centrally located, elongated cylindrical hollow shaft 18 which forms a portion of the body of the tool. As shown, the expanding die 17 is held in place between a lower shoulder 19 and collar 21 threaded onto the shaft. A plurality of movable arms 22, preferably provided with outwardly enlarged portions 23 near the top, are disposed in the form of a cylinder around shaft 18. The enlarged portions of the arms 23 upon being moved outwardly contact the liner to perform the final step of expanding the corrugated liner into a substantially cylindrical shape. The arm members 22 are pivotally attached to the shaft so as to be movable outwardly from the shaft by a tapered expanding member 24 slidably positioned on the shaft to serve as a second-stage expander. The surface of the member 24, as shown, moves upwardly along the shaft to engage with the arms and move them outwardly. Advantageously, the inside surfaces of the arms 22 and the outside surface of expanding member 24 form mating sections, typically octagonal in shape. The expansion of the arm members is controlled by the position of the member 24 which moves upwardly

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until it contacts shoulder 26 provided on the shaft. As member 24 moves in a downwordly direction arms 22 fold inwardly toward the shaft. The expanding arms 22 are held in place on the shaft by collar 27 and circular groove 28 provided on the shaft.

The expanding tool, comprising the first-stage die and the secondstage die is drawn through the liner to expand it in place in the casing. The
first-stage die provides a gross deformation of the liner so that it is
expanded outwardly against the wall of the casing. The second-stage die then
passes through the liner and performs the final expansion to smooth the inner
surface of the liner and to provide more even contact between the liner and
the wall of the casing and effect a fluid-tight seal.

In operation, the liner setting tool is assembled at the surface, as described above, and a glass cloth saturated with a resinous material may be wrapped around the corrugated tube to form the liner. The assembly is lowered into the well at the location at which the liner is to be set. A liquid, such as oil, is then pumped under pressure down the well tubing and flows through the passageway 29 provided in polished rod 31, through ports 32 and into cylinder 33 connected to the upper end of the shoulder 16. Upon the application of fluid pressure to the cylinder, the piston 34 secured to polished rod 31 moves upwardly in cylinder 33. As shown, rod 36 connects polished rod 31 and shaft 18 upon which is mounted the first-stage expanding die 17. When the piston 34 moves upwardly through the cylinder 33 the expanding die 17 and the secondstage die 22 are drawn upwardly into the corrugated liner 14 and "iron out" the corrugations in the liner, so that the expanded liner may contact the inside wall of the casing in which it is being installed. Positioned on the shaft below the expanding member 24 is a constant force spring member 37 which is employed to urge the expanding member against the expanding arms 22 with a substantially constant force. The force exerted against the arm members being substantially constant, the force transmitted through the arm members to the liner and to the casing will be substantially constant so that either sticking of the tool in the casing or rupture of the casing is precluded. Of course, the force provided by the spring member is preselected so that the frictional

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forces between the tool and the liner and the pressure exerted against the casing are maintained at predetermined safe levels. The constant force spring member assures that the contact pressure between the liner forming portion 25 of the arms 22 is great enough to provide the desired deformation of the casing, while preventing damage to the casing or to the tool.

The constant force spring member 37 is slidably mounted on the shaft 18 and held between the expanding element 24 and a cylindrical lower shoulder member 38 forming a portion of a differential sorew element 39 which transmits the losding on spring member 37 to shaft member 18. The differential screw element comprises shaft member 18 on the outside of which are cut male threads 18a, the lower shoulder member 38 provided with female threads 38a and thimble member 41 provided with threads 41a and 41b on the outside and the inside, respectively, to engage with threads on the shaft and the shoulder. The two sets of threads are coarse, such as square, modified square, or Acme threads, to withstand very high loads and differ in pitch so that shoulder 38 is moved upwardly on the shaft 18 when the shaft is revolved relative to thimble 41. The shoulder 38 is secured to the shaft 18 by splines 45 so that it can slide longitudinally, but it is not free to rotate on the shaft. Fixedly attached to the lower end of the thimble is a friction member, such as bow springs 42. a hydraulically actuated friction pad, or other such device for frictionally engaging with the inside wall of the conduit to secure the thimble against rotation with respect to the shaft. Preferably, the direction of the shoulder member threads 38a is the same as that of the shaft threads 18a, e.g. righthand threads, and the pitch, or lead, of threads 18a is slightly greater than that of threads 38s, with the pitch ratio being close to unity. In this manner, clock-wise revolution of the shaft relative to the thimble causes shoulder member 38 to advance upward slightly and a compression load is exerted upwardly on spring element 37 to cause buckling. For example, one satisfactory differential screw was made up using five and one-half threads/inch square threads on a shaft approximately 1.7-inch outside diameter and five and threequarters threads/inch square threads on a shoulder approximately 2.5-inches inside diameter.

Constant force spring element 37 comprises column element 43, advantageously consisting of a plurality of elongated columns disposed around shaft 18. Upper bearing plate member 44 is in contact with the upper ends of the columns and is slidably positioned on shaft 18 to transmit the force of the spring longitudinally against the bottom end of expander member 24. Lower bearing plate member 46 contacts the lower ends of the columns and is moved upwardly along the shaft by longitudinal movement of lower shoulder 38 as a result of revolving differential screw element 39. Grooves 47 are provided in each of the bearing plates, to form an upper race and a lower race, into which the ends of the columns are inserted. These grooves may be shaped to conform with the shape of the column ends if desired. A cover 48 may be employed to exclude foreign matter from the spring mechanism and to protect the spring.

A means for limiting the deflection of the columns is required. Although the column element functions in a buckled condition, application of excessive compressive load thereto would cause total failure or rupture of the columns. Therefore, a pair of stops 49 and 49a are provided for this purpose. As shown, the stops are rigidly connected to the bearing plates, and, in effect comprise upper and lower limiting sleeves positioned on the shaft to slide longitudinally thereon. The ends of the stops may move toward, or away from, each other as the load on the spring member varies. Lower sleeve 49a is prevented from moving down by lower shoulder 38 connected to the shaft 18. However, the spacing between the ends is such as to limit the longitudinal travel of the bearing plate members as they move together to prevent permanent deformation of the column element 43. Various alternative means for preventing damage to the column element may also be employed. For example, pins or rings mounted on the shaft may serve as stops, or the cover 48 provided with suitable connections may be employed for this purpose to limit longitudinal and/or lateral deflection of columns.

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The columns of the column element 43 may be arranged around the shaft 18, which as shown here forms a portion of the body of the spring device, with ends of the columns fitted in the races 47. The columns may be

fitted closely together as shown, or may be spaced around the race, with separators used between them to maintain the desired spacing. The number of columns employed will depend upon column characteristics and the materials of construction. For example, the slenderness ratio of the column may be varied widely, and the column ends may be round, flat, fixed or hinged. The preferred construction is a thin, slender column with rounded ends, free to move within the races shaped to the curvature of the column ends. Materials which may be satisfactorily employed for the columns are carbon and low alloy steels, chromium and nickel-chromium stainless steels, various copper base alloys, such 10 as phosphor bronze, beryllium copper, the high nickel alloys and other similar materials providing satisfactory mechanical properties. Typically, the individual columns are of long rectangular cross-section, with the width being greater than the thickness, and arranged so that the wider face of the columns is normal to the diameter of the shaft. Thus, with sufficient compression loading, the columns buckle, and bend about the axis having the least moment of inertia, e.g., outwardly away from the shaft lo.

For example, a group of columns 0.167-inch thick by 0.438-inch wide by 10.626-inches long, with the ends rounded, were fabricated from A.I.S.I 4340 steel, quenched and drawn at 575°F. Each column was found to require a 20 critical compression loading of 450 pounds in order to buckle the column. After buckling, the columns were found to have a very flat spring characteristic, as shown in Figure 3, wherein  $P_{\mathbf{c}}$  is the critical buckling load and point C represents the load and deflection at which the stress in the extreme fibers of the column exceed the yield point of the material. Theoretically, the shape of this spring characteristic curve is described by curve OA'ABC. Actually, this curve is described by OABC due to friction in the system. Points A and B represent typical working limits, which, of course, may be varied according to the application for which the spring is designed. For example, where a large number of flexing cycles are not anticipated, a working stress just below the 30 yield point may be used, while with a great number of flexures, the working stress may be held to less than the endurance limit of the material of construction. In the above-mentioned tests, the lateral deflection was limited to

approximately one inch, at which the longitudinal deflection was approximately: 0.225 inches. From zero deflection to the maximum deflection, the 450-pound loading was found to be substantially constant.

In another test a spring device was built, as shown, employing 20 columns, each having a critical buckling load of 1250 pounds. The lateral deflection was limited between 0 and about 1.00 inches by appropriately positioning the stops. Upon compressional loading, the spring element buckled at substantially 25,000 pounds and from a longitudinal deflection of 0.04 inches (buckling) to about 0.15 inches the load remained substantially at 25,000 pounds.

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Of course, in designing a spring element as above it is advantageous to obtain the greatest possible value of longitudinal deflection for specified values of lateral deflection and critical buckling load, while maintaining the stress level in the columns at a safe level. The preferred columns, therefore, are laminated, as shown in Figures 1B and 2, with multiple flat members making up each column.

In the operation of the above expanding tool for setting a liner in vell casing, the made-up tool is lowered into the vell as mentioned above, with the arms 22 in the retracted position. When the tool is at the desired level, the vell tubing is revolved. The friction member \$2\$ engages with the wall of the casing and prevents thimble \$1\$ from revolving. With several revolutions of the tubing, lower shoulder 38 is moved upwardly by differential screw 39 to buckle spring element 37 which has a predetermined critical buckling load. This load is transmitted upwardly against the lower end of expander 24, and its tapered surface is engaged with the tapered surface on the inside of the arms 22 to urge the arms outwardly with a substantially constant force proportional to the critical buckling load of the spring element. Subsequently, the expanding tool is passed through the liner to expand it in the casing in the manner described hereinbefore.

The foregoing description of a preferred embodiment of my invention has been given for the purpose of exemplification. It will be understood that various modifications in the details of construction will become apparent to

the artisan from the description, and, as such, these fall within the spirit and scope of my invention.

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#### I CLAIM:

- 1. A device for expanding a metallic liner inside a conduit which device comprises a shaft element, an expanding die member attached to said shaft element, said die member comprising a movable liner-forming member positioned on said shaft and being radially movable in respect thereof to contact said liner, an expander member slidably positioned on said shaft between said shaft and said die member to move said liner-forming member from said shaft, and a constant force spring member positioned on said shaft to contact said expander member and to maintain said expander member against said liner-forming member, whereby said liner-forming member is urged against said liner by a substantially constant force.
  - 2. In a device for installing an expanded metallic liner in a conduit wherein an expanding die is moved through a liner positioned in said conduit to expand said liner: a cylindrical shaft element, an expanding die member attached to said shaft, said die member comprising a plurality of arm members disposed around said shaft and being pivotable cutwardly therefrom to contact said liner, a cone member slidably positioned on said shaft between said shaft and said arm members to urge said arm members outwardly from said shaft, and a constant force spring member positioned on said shaft to contact said cone member and to maintain said cone member in contact with said arm members, whereby said arm members are urged outwardly by a substantially constant force.
  - 3. The device of Claim 2 wherein said constant force spring member comprises a plurality of columns disposed around said shaft, a first bearing plate member and a second bearing plate member, each of said bearing plate members contacting opposite ends of said columns, at least one of said bearing plate members being movably positioned on said shaft and being in contact with said come member, stop means connected to said shaft to limit the axial travel of said movable bearing plate member along said shaft, and compression means for maintaining a lateral deflection in said columns.

- 1 4. The device of Claim 3 wherein said compression means comprises 2 a differential screw connecting said spring member and said shaft.
- 1 5. The device of Claim 3 wherein said stop means comprises a sleeve-like element connected to said movable bearing plate member and 2 slidably positioned on said shaft and a member connected to said shaft to 3 limit the travel of said sleeve-like element.
- 1 6. The device of Claim 3 wherein said columns have a rectangular cross-section, the width being greater than the thickness, and having the 2 3 wider face normal to the diameter of said shaft.
- 1 7. A device for installing an expanded metallic liner in a conduit which comprises a cylindrical shaft element; an expanding die member mounted 2 on said shaft, said die member comprising a plurality of arm members disposed 3 circumferentially around the outside of said shaft and being pivotable outwardly therefrom to contact the liner; a conical expanding member slidably 5 positioned on said shaft between said shaft and said arm members to urge said 6 arm members outwardly from said shaft; a plurality of slender columns, each 8 having a long rectangular cross-section and disposed circumferentially about said shaft; an upper bearing plate member and a lower bearing plate member, 9 each slidably positioned on said shaft and contacting opposite ends of said 10 columns; limiting sleeves attached to each of said bearing plate members 11 and slidably positioned on said shaft; a shoulder member on said shaft; a 12 differential screw element connecting said shoulder and said shaft to apply 13 a buckling load to said columns; said shoulder being engageable with the limiting sleeve connected to said lower bearing plate member, whereby the axial travel of said bearing plate members is limited; said column members transmitting their buckling load to said arm members to urge said arm members outwardly with a substantially constant force.

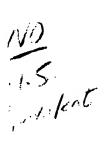
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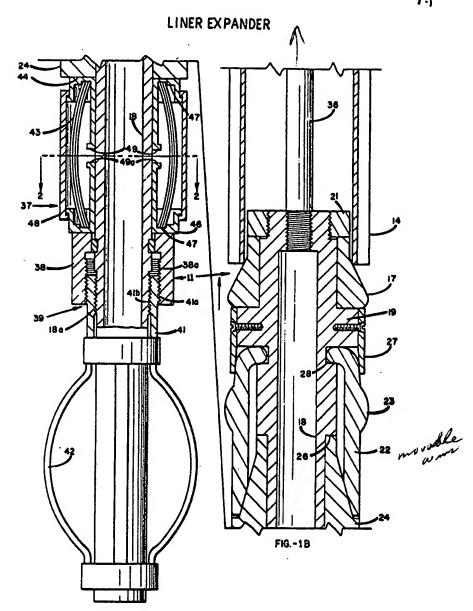
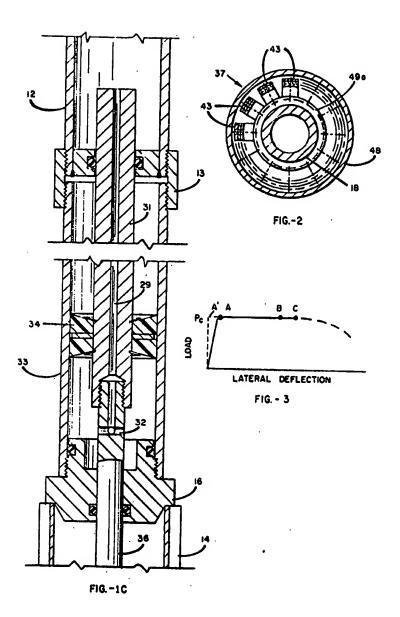


FIG.-1A



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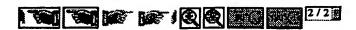
2. In a derice the installing an expended astallic liner in a constail therein an expending die is moved through a liner positioned in said stathed to explain said liner; a cylindrical short element, an expending die seather attached to said short, said die seather comprising a plusality of any sustaine disposed around said short and being pivotable unbankly therefore to outstart stid liner, a cone number salidably positioned on said short between said short and said and manhors to very said arm amount colorately from said short, and a constant force spring number positioned on said start to content said once number in acceptant this said arm numbers, whereby said arm numbers, whereby said arm numbers, whereby said arm numbers are unged outstartly by a substantially constant force.

3. The device of Claim 2 stands and comban force spring coder comprises a plantity of orderms disposed scower said shorts, a first boaring plate context and a second bearing plate coder, each of said boaring plate coders contexting opposite code of said columns, at least one of said bearing plate members being morehly positioned on said staff and being in context with said come number, stop moure commerced to said staff to limit the axial traval of said morehly boaring plate member along said shaft, and compression means for maintaining a interal derication in said columns.

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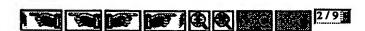
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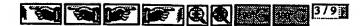


Figure 2 is a sestional view of the apparatus of Figure 1A tabes at

Figure 3 is a typical plot of applied lost versus Deflection for the complete force spring device of the Levestion.

Referring to the drawings, Figure 16 is the lotter portion of a liner expending tool for one in installing a metallic liner in a well, while Pignre 10 tilustrates the siblic section of such a tool and Pignre 20 represents the upper section of the tool. The expending tool il is obtached to well testing 15 by compling 15 and, typically, may be loosed from the surface through a well cosing (not shown) to a point in the sorted at which th is desired to imply a metallic liner. Before inserting the test into the well, an alcogated surtically corregated lines in fabricated from alld steel, or other suitable mileshie seterial, is placed on the too). The corrupted liner is occurred in position by cambot at its upper end with a cylindrical shoulder marker 16 and, at the lower and hy contact with a first-stage expanding die ly in the form of a truncated circular cose which serves as a firstading die in the sevent bereinefter described. The expanding die in firedly edienhed to a centrally located, elongated cylindrical bollow shaft lo which forms a portion of the body of the tool. As shows, the expending Sic 17 is held in place between a lower abouter 19 and collar 21 threaded outo the short. . A plurality of morehia arms 29, preservably provided with outsently quierget portions 25 mar the top; who disposed in the form of a sylinder nd that's 18. The calarged portions of the sens 23 upon being soved outstook the liner to perfore the final step of expending the sucregated of to the sheft on as to be movehic publically from the sheft by a tapered expending number 26 slidebly positioned on the sheft to serve as a second-stage day. The equience of the member 24, as shown, moves specially along the start to sugage with the erms and more them outwardly. Advantageously, the intide surfaces of the expa 22 and the outside surface of expending member 24 seting sestions, typically cotogonal is shape. The expension of the arm is controlled by the position of the mester 94 risch mosts openally



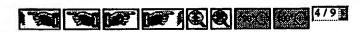


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mail) it contacts simples 26 provided on the staff. As number 26 wowe in a dominarily direction area 52 fald invarily toward the shaft. The expending area 22 are held to place on the shaft by collect 27 and circular groom 26 provided on the shaft.

The expending tool, comprising the flux-stage die and the secondstage die is drawn through the liner to expend it in place in the content. The flux-stage die provides a gross differention of the liner so that it is expended outworthy against the well of the energy. The second-stage die them passes through the liner and perform the final agreemen to enough the inner surface of the liner and to provide more even content between the liner and the well of the casing and effect a finid-tight soul-

In operation, the liner setting tool is assembled at the seriesc, so described shows, and a glass sloth seturated with a resiscons natorial may be erapped around the corrugated tone to form the liner. The assembly is lovered into the well at the leastion at which the liner in to be set. A liquid, such so oil, is then proped under presence down the well taking and flows through the papergramy 29 provided is polished rod 31, through ports 50 and into egilader 35 consisted to the upper end of the shoulder 16. Upon the application of finds pressure to the sylinder, the piston % second to poliched rol 31 moves appearably in expirator 33. As shown, rod 36 consects polished rod 31 and shaft 15 mon eitigh is mounted the First-stage expending sie 17. - then the piston % rely through the splinder 33 the expending die 17 and the secondstage die 22 are dress upwartly into the corrupted liner it and "iron out" the corregations to the liner, so that the expedded liner may contect the incide well of the ceaing In which it is being installed. Poritioned on the shaft below the expending mester th is a comment tures spring mester 27 which is employed to trips the expending number against the exploiting star 22 with a substantially sometant force. The force exerted against the are senters being substantially substant, the furce transmitted through the arm masters to the liser and to the suring will be substantially accordant so that either sticking of the tool in the casing or repture of the casing is precluded. Or course, the ctros provided by the spring member is preselected so that the friethers!



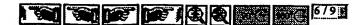
and management of the companies and the companies of the



forces between the tool and the liner and the presence emerted defined the assing are extracted at presentantised safe levels. The constant force spring
mades assumes that the contact presence between the liner founds portion 25
of the core 22 is great enough to provide the derived detremation of the costtion, while recognition departs to the contact or to the tool.

The equators force spring seasor 77 is alidebly nousted on the shall is seed hald bytemen the expending alsosped 20 and a cylindrical lever chealder seasor 30 forcing a portion of a differential server alsone 39 which betweeners the looking on spring number 37 to easit masher 18. The differential server alsoned comprises shall under 18 on the outside of which are one sale threads also the lower shallow masher 30 provided with funds threads 30s and thinkle number 31 provided with threads also and 31b on the criticle and the institute and the institute of the institute, to supage with threads and ship on the criticle and the shoulder. The two sets of threads are source, such as square, modified equare, or form threads, to withstand very high loads and differ in prich so that shoulder 39 is severed appearity on the shart 18 when the shart 16 by splinns 45 so that at can alide implicationally, but it is not tree to rotate on the shart. Finally attached to the lower seet or the thinkle is a friction masher, such as low springs 32, as apprentically estuated friction pass, or other such series for frietionally masher threads 30s is the same as that of the court threads 18s, e.g. right-head threads 30s, is the pitch, or load, or threads 30s is slightly greater man that of threads 30s, with the pitch rotate threads 30s is alightly severe man these of threads 30s, with the pitch rotate being alone to unity. In that summers, clock-wise respicution of the shart relative to the thinkle sames threads on a chart approximately 1.7-tach cutains dissector and five and threads on a chart approximately 1.7-tach cutains dissector and five and threads inside dissector.





Constant force spring element 37 comprises subman element 53, etwentageously constitute of a plurality of alongsied solume étiquied around short 18. Upper bearing plate confect th in in contact with the apper ends of the solume and is although positioned on shart if to bremouth the force of the spring longitudinally against the bottom and of expander sendor 28. Lover hearing plate number 56 confects the house and of expander sendor 28 as a result of revolving fifteenight source adminst 39. Greaves 47 are provided in send-or the hearing plates, to form on upper once and a lover once, into which the case of the column are insented. These greaves my be simped to contain with the shape of the column only it desired. A cover 48 my be employed to another foreign author from the spring mechanism and to protect

A means for limiting the deflection of the columns to required.

Although the column element functions in a buckled condition, application of appearing accuracy to the theorem and the same total failure or repture of the column. Therefore, a pair of stops by each tips are provided for this purpose. As shown, the stops me registly commerced to the bearing yields, and, in affect comprise upper and lower limiting starvas postelored on the shaft to alide longitudinally thereon. The under of the stops may agree toward, or may from, each other as the load in the spring number vertex. Lower shows the prevents from mosing dama by loader shoulder 38 connected to the chart 18. Reserve, the spacing between the code is much as to limit the longitudinal travel of the bearing plate numbers on they move together to prevent persented deformation of the column almosts by. Warious alternative manus for preventing damage to the column almosts by also be employed. For example, plat or rings sometaid on the other may serve as atops, or the cover 18 provided with entitle connections may be sublicited for this purpose to limit longitudinal and/or lateral serfaction of columns.

The columns of the calmen element 45 may be arranged except the chart 16, which as shows here forces a portion of the body of the spring ferring, with each of the columns fitted in the recess 57. The columns may be





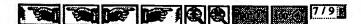
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ritted closely together as shows, or may he spared around lim rice, with separature used between them to meisteds the desired spacing. The resolut of column smpleyed will depend upon column sharestatics and the materials of construction. For excepts, the significancy ratio of the column may be varied widely, and the column ends may be round, fluct, fluct or kinged. The preferred construction is a thin, element column with rounded main, free to now within the races shaped to the coverbers of the column ends. Reterials which may be estimated and support the appearance of the solumn ends. Reterials which may be estimated and maintain ends at a think of the extension of the solumn ends. Reterials which may be estimated and actional-elements estimated on the state allow and other similar estimates providing actionactory weekenders, with middle vides shall being greater than the thickness, and arounged so that the wides face of the notweekender than the the climater of the shart. Thus, with surficient conservation loading, the columns backle, and bend about the early laying the loast covert of inertia, e.g., outstainly may from the shart 15.

For example, a group of columns 0.15f-inch thick by 0.838-inch wide by 10.636-inchew long, with the ends recorded, were febricated from A.L.S.I.

1360 stand, granuland and drawn at 575°F. Bush column was found to require a critical compression loading of 150 pounds in order to buckle the enture.

After buckling, the columns were found to have a very fish opting characteristic, on shown in Figure 3, whereis Polis the critical buckling load and point 0 represents the load and deflection at which the stress in the externe fibers of the delians exceed the yield point of the untertail. Theoretically, the shape of this spring obstantaristic curve is described by carra 04'180. Actually, this curve is described by 0400 fine to friction in the system. Foldes A and 2 represent typical screen by 0400 fine to friction in the system. Foldes A and 2 represent typical screen limits, which, af course, say be varied according to the application for staich the spring is designed. For example, where a large number of floring system are not motificiented, a working stress just below the yield point may be used, while with a great number of florings, the vorking stress may be held to less than the antervace that of the exterial of construction. In the above-municoust basis, the lateral staffection was Mattal to





egyrocinetely one inch, at which the longitudinal deflorMen was approximately 0.225 inches. From more deflection to the sections deflection, the \$50-pound loading was fromt to be substantially constant.

In smother teat a spring device was built, as shown, employing 80 columns, each having a critical bushing load of 1850 years. The internal enclassion was limited between 0 and about 3.00 inches by empregalately positioning the stope. One compressional loading the spring element buckled of enternality 85,000 pounds and from a longitudinal deflection of 0.05 inches (bushing) to stook 0.15 inches the load remained substantially at 85,000 teacher.

Of course, in dorigining a spring element as above it is advantagement to obtain the greatest possible value of longitudinal defination for specified values of laboral defination and critical bushing load, while unintelling the stress lovel is the columns at a cafe lovel. The preferred columns, therefore, are laminated, as shown in Figures 18 and 2, with emitiple flat anothers unling by each column.

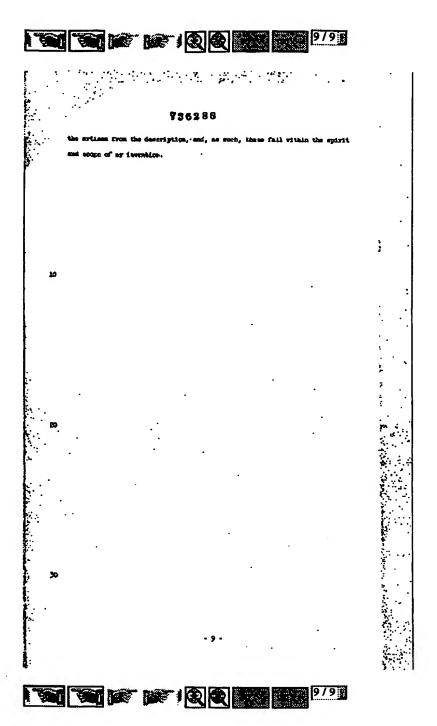
In the operation of the shows expending tool for setting a liner in well emerge, the and-up tool is lowered into the well as sectioned above, with the area 22 in the retreated position. Show the tool is at the Section 12 level, the well taking is revolved. The fristen mether his comages with the wall of the maning and prevents thinks in from revolving. With several revolutions of the toling, lower chemiser 35 is moved assembly by differential server 39 to bush a spring almost 37 which has a predriessioned existent bushing load. This lead is transmitted assembly against the lower and of expender 25, and its topered curious is engaged with the importal surface on the lastice of the oran 25 to urge the tune cutturally with a substantially constant force proportional to the critical bushing load of the spring almost. Subsequently, the expending tool is passed through the liner to expend it in the caping in the secont described hereinbefore.

the foregoing description of a preferred embeliant of my investigahas been given for the purpose of examplification. It will be understood that verious madifications in the descript of accordance will become appearant to

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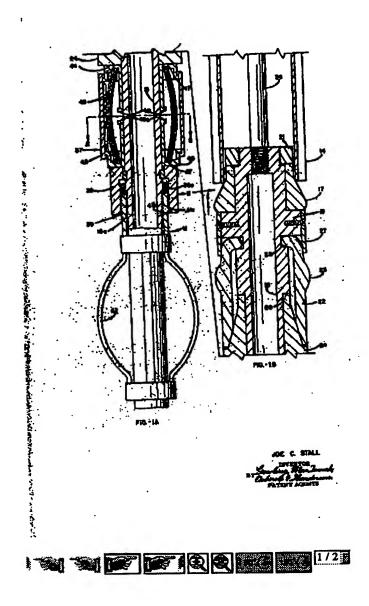
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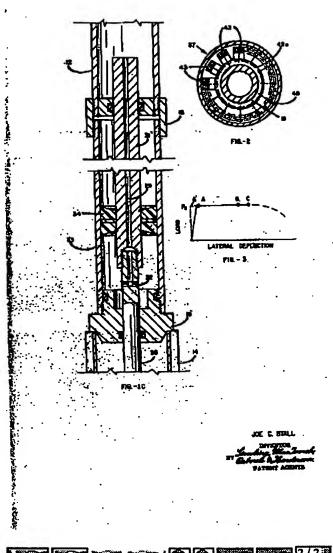


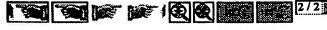


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